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The Utilization of Self Compacting Concrete (SCC) in Producing Hollow Concrete Panel Wall to Provide Rapid Shelter for Post Disaster Area

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Abstract

The fact that Indonesia is located in the Pacific Ring of Fire in which some big earthquakes frequently occur has increased concern on the needs for temporary shelter and building safety. Hence, the use of lightweight pre-cast wall becomes one of the ideal choices to fulfill the need of rapid temporary shelter and to increase building safety. This paper reported the investigation of the properties of pre-cast hollow concrete wall panel with different thickness of partition using self compacting concrete technology. The test of concrete properties consists of compressive strength of mortar, flexural strength of hollow concrete wall, the density of the wall. In addition, the flexural strength is tested on the hollow concrete panel wall with the dimension of 1,000 x 300 x 120 mm. The result shows that the hollow concrete panel wall satisfies the properties requirement for concrete wall. Moreover, the pre-cast hollow concrete panel wall with the partition thickness of 15 mm is the most optimum dimension of the panel wall and becomes one of appropriate technologies to provide rapid shelter for post disaster area.

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Keyword: hollow panel wall, self compacting concrete, temporary shelter, post disaster area

1. Introduction

Indonesia is situated at the area known as 'ring of fire', an area on which a sequence of volcanoes is located. The position leads to frequent earthquake. Some of the big earthquake happened in recent years for example Aceh earthquake (2004), Nias earthquake (2005), Yogyakarta earthquake (2006), and Madina earthquake (2006). The

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Aceh earthquake which is followed by tsunami is recorded as the second biggest earthquake in this century after Alaskan Earthquake in 1964 (Dewobroto, 2005).

The earthquake phenomenon has brought much scholarly concern especially on building safety. One of the methods to increase the building safety is by reducing the self-weight of structure as the higher the self-weight of structure, the higher earthquake load of a building. One of building elements whose weight can be reduced is wall or partition. Wall is not a structural element of building, and the strength requirement for the wall is very low. However, brick which is a heavy material is commonly used as wall material for building in Indonesia. Hence, the reduction of the self-weight of structure can fulfilled by using light weight wall for substitution of brick wall.

There have been some recent researches investigating light weight panel wall. Hatta (2004) examines the use of Styrofoam as aggregate in concrete wall panel resulted in reasonably significant decrease of wall panel density (643,46 kg/ m^3) in comparison to that of brick wall (1,400 kg/m^3). However, the paste of fresh concrete is so clammy that it is difficult to put in the formwork (Hatta 2004). In addition, the use of Aerated Lightweight Concrete for wall panel also resulted in lightweight concrete wall (Hoedajanto et. al., 2007). Aerated Lightweight Concrete is made by introducing air or gas into concrete by using foam admixture and employing pressure steam curing as curing method. Although Aerated Lightweight Concrete seems to become alternative for wall, the dense process of its production makes it inapplicable for wide use.

This paper examines the possibility of utilization of a new concrete technology called self compacting concrete (SCC) which is named as: the most revolutionary development in concrete construction for several decades (EFNARC, 2002). The technology is introduced firstly in Japan in 1988 to eliminate the use of vibrator for compaction (Wu et. al., 2009). The material for self compacting concrete is same as normal concrete material, however; a high quality of superplasticizer to significantly reduce the amount of water and to maintain the workability for a long time (Prajitno, 2007).

By using self compacting concrete, it is possible to produce hollow concrete wall with thin partition resulting in a honeycomb concrete panel. Therefore, the weight of concrete wall will decrease significantly in comparison to the weight of solid concrete wall.

Regarding with rapid shelter for post disaster area, the use of light weight element with high performance as building component such as wall panel would be very useful. This is because the light weight pre-cast building element would be easy to construct in post-disaster area due to the limitation of worker and equipment (Bradford and Sen, 2005). Besides, the use of lightweight material will increase the safety of building as less weight of structure leads to less earthquake load.

2. Research Objective

This paper reports the investigation of the properties of pre-cast hollow concrete panel with different thickness of partition using self-compacting concrete technology.

This research will find out optimum dimension of pre-cast hollow concrete panel which satisfy the requirement as partition material in post disaster area.

3. Research program

Hollow concrete panel was produced by casting concrete wall with thin partition inside. Additionally, all of the wall partition is filled with wire mesh as concrete reinforcement. The pre-cast hollow concrete panel is proposed to get the lightweight concrete panel wall which meets the standard requirement as wall. Moreover, pre-cast hollow concrete panel is one of alternative wall materials for building rapid shelter in post-disaster area. The dimension of the wall panel specimen is 1,000 x 300 x 120 mm, and the thickness variations of partition are 15 mm, 20 mm, and 25 mm as shown in figure 1.

The construction of thin partition in the wall is made available by using self-compacting concrete technology. The technology enhances the concrete workability so that it can fill up thin formwork without the need of any compaction. The self compacting concrete to fill up the thin partition of the wall is a mortar concrete made of cement, sand, water as well as high quality super-plasticizer admixture which is added to significantly increase the workability of concrete. The concrete workability is tested by using mortar flow test. Moreover, while thin partition formwork is used in producing the panel, the coarse aggregate is not used.

Once the fresh mortar is ready, it is cast in hollow panel formwork for flexural strength test and in cube mold of 100 x 100 x 100 mm^3 for compressive strength test. On the following day, the formwork is opened and the panel is cured for 28 days. The test of concrete properties consists of the tests on compressive strength of mortar, flexural strength of hollow concrete wall, and the density of the wall.

4. Materials

The materials to produce self compacting concrete are type I cement, crushed sand, water, and Superplasticizer. As thin partition is used for the wall panel, the wire mesh has side dimension of 1 mm and hole of 25 mm^2 is used as concrete reinforcement inside the partition.

To increase the workability of mortar as self-compact concrete, a modified polycarboxylates type of superplasticizer admixture is used. It is commercially named as Sika-viscocrete-10, a High range water reducer and retarder with pH of 4.3.

The hollow concrete wall panel has dimension of 1,000 x 300 x 120 mm as shown in Figure 1.

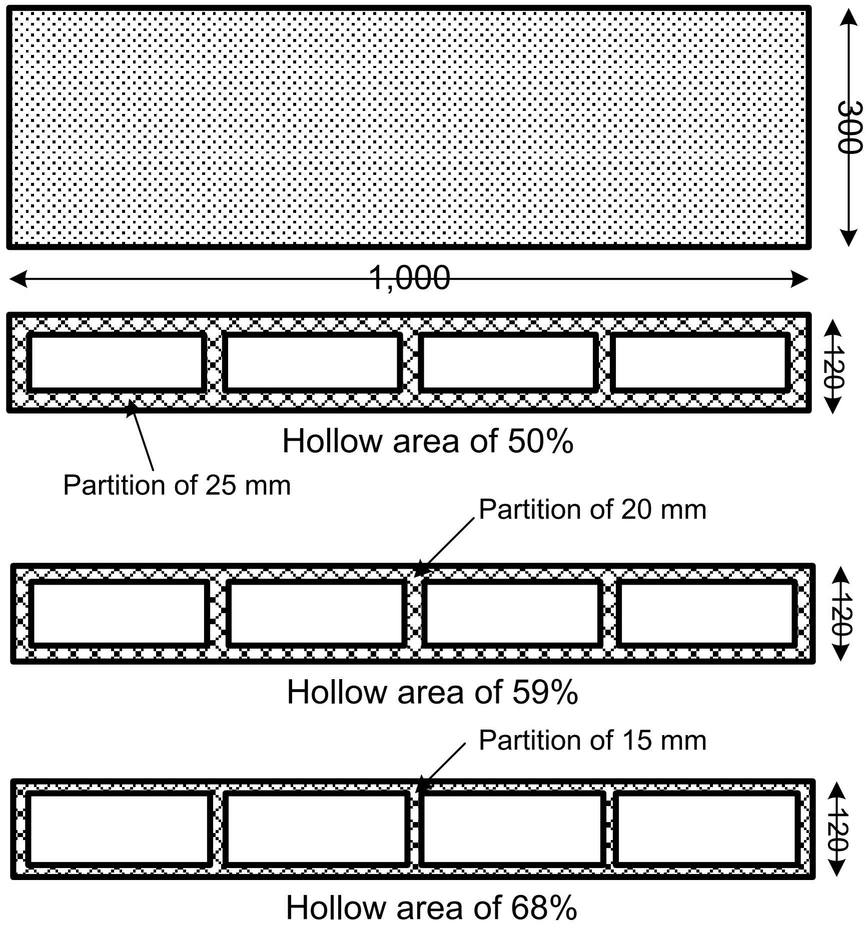

Figure 1. Hollow concrete panel

There are three thickness variations of partition, i.e. 15 mm, 20 mm, and 25 mm. The Figure 1 shows that the thinnest partition results in the highest hollow area. The weight of this highest hollow area is possibly to be the least of all the wall panels; however, its properties need to be further compared to the other partition thickness in laboratory experiment.

5. Mix Proportion

The mix proportion of self compacting concrete is made with the specific gravity of Portland cement 3.15, water 1 and SSD density of sand 2,513 kg/m^3. In addition, the density of Superplasticizer is 1.06 kg/liter. Based on ASTM of testing of hydraulic cement mortar, the ratio of sand to cement is 2.75, and the water cement ratio (w/c ratio) used is of 0.45 (ASTM C 190-02, 2002). The mix proportion to produce the volume of 1 m^3 of mortar is shown in the Table 1.

Table 1. Mix proportion

Mix proportion		
Cement	(kg/m^3)	495.00
Water	(kg/m^3)	222.75
w/c ratio		0.45
Sand	(kg/m^3)	1,361.00
Plasticizer	(litre/m^3)	15.00

The use of cement for the mix proportion is quite high in comparison to mix proportion of normal strength concrete, which usually uses cement around 190 kg/m^3 for normal compressive strength of 20 MPa (Boon, [no date]). The high content of cement used is typical of mix proportion of self compacting concrete (Wu et al., 2009). Besides, as sand is the only aggregate in mortar, so the sand content is also high.

6. Result and Discussion

6.1. Properties of concrete

The investigation of properties of self-compacting concrete comprises of mortar flow test and the density test of hollow panel concrete wall. The mortar flow test investigates the workability of concrete focusing on the homogeneity of self-compacting concrete. This homogeneity is significant to examine especially when thin formwork is used or congestion of reinforcement occur (Schutter, 2005).

Furthermore, the mortar flow test is conducted to investigate the deformability of Self compacting concrete by measuring the spread diameter of the fresh concrete after removing it from conventional slump cone. The deformability of mortar is calculated using the following equation

$$\Gamma_m = \frac{[(d_1 \times d_2) - 100]}{100} \tag{1}$$

Where:

Γ_m :deformability

d_1 : first diameter of spread mortar

d_2 : second diameter of spread mortar

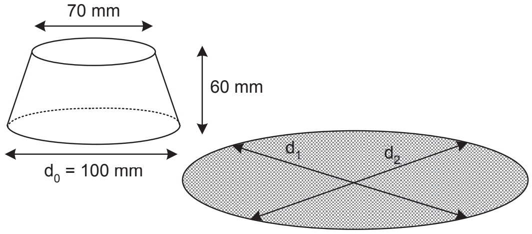

Figure 2. Mortar flow test

The result of mortar flow test on the experiment (9 data) is shown in Table 2

Table 2. Deformability of mortar

No	d_1 (mm)	d_2 (mm)	Γ_m
1	240	240	4.76
2	230	230	4.29
3	280	260	6.28
4	240	260	5.24
5	250	240	5.00
6	270	250	5.75
7	250	280	6.00
8	260	240	5.24
9	270	240	5.48
	Average =		5.34

The average deformability of the self-compacting concrete is close to ideal value of deformability of 5. Therefore, the mortar is considered as homogeny concrete and there is no segregation.

The weight of hollow concrete wall panel before the flexural strength test is shown in Table 3.

Table 3. Weight of concrete hollow wall panel

wall panel	Partition thickness	Panel weight (kg)	Panel weight (kg/ m^2)
Type I	15 mm	23.5	78.33
Type II	20 mm	30.5	101.67
Type III	25 mm	37.8	126.11

Dimension for the panel is 1000 x 300 x 120 mm

The weight of hollow concrete wall panel result shows that all type of the wall panel has less weight in comparison to self-weight of brick wall i.e.: 255 kg/m^2. The decrease of weight in comparison to brick wall for type I, type II and type III of hollow concrete panel are 69.3%, 60.1%, and 50.5% respectively. The significant decrease of the self-weight makes the use of the panel as wall very useful in reducing self-weight of the building and lead to the increase of building safety in earthquake load area.

6.2. Strength of concrete

The strength test of hollow concrete wall panel consisted of compressive strength of Self compacting concrete mortar and flexural strength of the wall panel. Both tests are conducted after 28 days of curing the specimen. The compressive strength of mortar is tested using compressive test machine whereas the flexural strength of the wall panel is tested using 3 point bending load test.

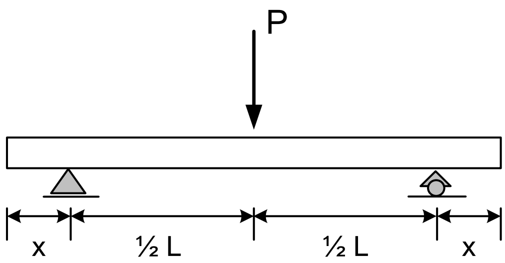

Figure 3. Set up for Flexural test of hollow concrete wall panel

The compressive strength test result of self compacting concrete from nine cubes specimens is shown in Table 4. In addition three point load bending test for flexural testing of the wall panel is shown in Figure 3.

Table 4. Compressive strength of self compacting concrete mortar

Specimen	**Max load (kN)**	**Compressive strength (MPa)**
No. 1	590.0	26.22
No. 2	625.0	27.78
No. 3	665.0	29.55
No. 4	660.0	29.33
No. 5	680.0	30.22
No. 6	650.0	28.89
No. 7	690.0	30.67
No. 8	720.0	32.00
No. 9	670.0	29.38
Average strength		29.95

With the mean strength of 29.95 MPa, the characteristic strength of self compacting concrete is, f_c' = 25.79 MPa which is more than the strength requirement of concrete wall panel i.e. 10 MPa (SNI 03-0349, 1989). Besides, the strength of the mortar shows that the self compacting concrete meets the minimum requirement as concrete structural component especially in earth quake region which is stated, 20 MPa as the minimum strength of concrete in earthquake area (SNI-1726, 2002).

As the compressive strength result is higher than minimum strength requirement and the wall panel is not a structural component of the building, the mix proportion of self compacting concrete can be modified to reduce the strength to be close to minimum strength requirement.

Table 5. Flexural test analysis of hollow concrete wall panel

hollow Concrete wall panel	Partition thickness	Self weight	Point load	Deflection	Maximum length	Ratio length to weight
Type I	15 mm	0.235 kN/m	29 kg	0.28 mm	1.50 m	1.74
Type II	20 mm	0.305 kN/m	58 kg	0.23 mm	2.25 m	1.06
Type III	25 mm	0.378 kN/m	86 kg	0.22 mm	2.50 m	0.74

Dimension for the panel is 1000 x 300 x 120 mm

Figure 4. Set up for Flexural test of hollow concrete wall panel

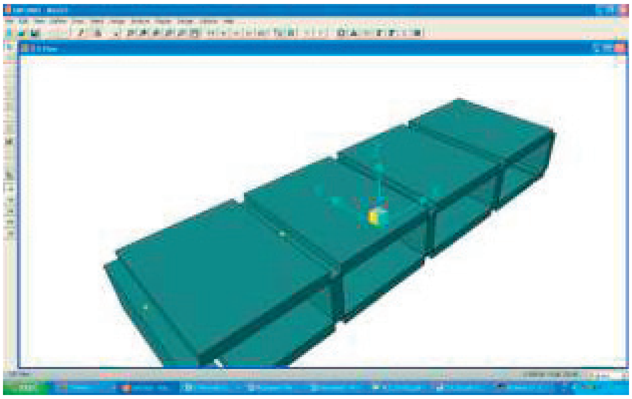

Figure 5. Extrusion of hollow wall panel in SAP 2000

In addition since the wall is a non structural of building element, therefore the flexural strength is needed upon the transportation caused by self weight of the wall. Moreover the maximum length of the wall was analyzed based on the maximum deflection of flexural concrete element follow this equation (ACI 318R-02, 2002)

$$\Delta_{max} = \frac{l_t}{20000 \times h} \quad (2)$$

Where:

Δ_{max} = measured maximum deflection

l_t = span of member under load test

h = overall thickness of member, in this research h equal to $^1/_6$ of lt.

To find out the maximum length of each variation of the wall, load and deflection analysis was conducted using SAP 2000 structural analysis program. To start with, the deflection data and the appropriate point load of each wall were used to adjust the strength properties of hollow concrete wall panel, i.e.: moment inertia and shear strength of the wall. Once the appropriate strength properties of the wall were found, then the properties were used to calculate the maximum length of the wall which was caused by self weight of the wall without exceed the maximum deflection as stated in Equation 2. The load factor of 1.4 was applied for the self weight of the wall when analyzing the maximum length by trial and error in SAP 2000. The load deflection and the analysis result of maximum length for each wall panel is shown in Table 5.

The result of flexural strength test shows that the increase of the thickness of partition of hollow concrete wall panel increases the load for the same deflection. Furthermore the increase of the load leads to the increase the maximum length of the panel.

To find out the optimum thickness of hollow concrete wall panel, the un-dimensional analysis of self weight and the maximum length ratio was conducted. The result shows that the hollow concrete wall panel with the partition thickness of 20 mm is considered as the optimum wall panel as it has the highest ratio.

6.3. Analysis of utilization as disaster relief component

One of the purposes in investigating concrete hollow panel wall is to use it as structure component for rapid shelter for post disaster area. Therefore, dimension of the optimum wall panel should be re-analyzed. The analysis of the dimension is based on material constructability which gives criteria that every single component for emergency shelter in post disaster area should not be too heavy or should be less than 355.4 N (35.5 kg).

For that reason the hollow concrete wall panel with the partition of 15 mm would be used. With the wall panel weight of 235 N/m (23.5 kg/m), the propose dimension for single concrete hollow panel wall is 1.5 x 0.3 m^2 which results in single component weight of 352.5 N. The propose dimension meets the constructability criteria for the maximum weight of each component (Bradford and Sen, 2005).

7. Conclusions

The result of this research demonstrates that local material can be used to produce self compacting concrete. The strength of self compacting concrete, which is more than concrete strength requirement in earthquake area, make the self compacting concrete is valuable to be used both as wall panel and as material for any construction.

Moreover, by using hollow concrete wall panel the weight of wall decreases significantly in comparison to the weight of brick wall especially for the wall with partition thickness of 15 mm with the decrease of self-weight can reach up to 65.2%. This decrease of the self weight will be very useful for the building safety when earthquake occurs.

Furthermore, the hollow concrete wall panel can be used as emergency shelter in post-disaster area. By using the dimension of 0.3 x 1.5 $m^{2,}$ the weight of the wall meets the criteria of constructability for the maximum weight of each building component.

As this research uses 120 mm thickness, further investigation should be made on different thickness of the wall panel. In addition, the durability of concrete should be investigated as the concrete cover for reinforcement is thin.

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